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Sustainable Building Rating Systems Assessment and Difficulties in Sustainable Design as a Structural Engineer

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Abstract

In a world with limited natural resources and growing needs, securing current conditions without decreasing future generations' ability to supply their needs is a significant challenge, and sustainable development with this concept has become one of the main topics in the present and future. The construction industry is one of the most critical and active industries that must be more advanced and increase its knowledge in sustainable development. In the present study, at first, different sustainable building rating systems were assessed with a focus on structural engineering and sustainable design, then the structural engineer as one of the essential roles of the construction industry discussed. Finally, while drawing the actual position of Structural Engineers in Sustainable Development, we will discuss challenges and guidelines in the Sustainable Design of Buildings.

Keywords: Sustainable development, Structural engineering, Rating systems, green buildings, Sustainable design.

1. Introduction

Providing for today's needs without compromising the ability of future generations to meet their own needs is one of the most straightforward definitions of sustainable development, as presented by the World Commission on Environment and Development in 1987. The goal of sustainable development, which according to the United Nations, includes four main branches and 58 sub-branches, is to create a sustainable relationship between the environment, economy, and society so that while meeting present needs, the continuous improvement of quality of life and preservation of the environment is achieved. The needs of future generations and how to meet them are also considered. As stated in the 50th article of the Constitution, achieving sustainable development requires sufficient research and implementing strategies designed to achieve it [1].

As mentioned, sustainable development has many indicators, necessitating extensive research in various areas for its realization. One of these areas is the construction industry, which is particularly important due to its direct impact on the four main branches of sustainable development: environmental, economic, institutional, and social indicators [1]. Therefore,



conducting sufficient research to create necessary policies to achieve crucial sustainable development goals in the construction industry is more essential than ever.

This article first introduces and compares green building rating systems as a targeted framework for implementing sustainable development in the construction industry. Then, the role of structural engineers as one of the main pillars of this industry about sustainable development is examined. Finally, by introducing and reviewing sustainable design criteria, several case studies are presented to evaluate these criteria in practice, and efforts have been made to create suitable patterns for engineers to draw on in designing sustainable structures.

2. Green Building Rating Systems

New and endless challenges in the field of engineering require engineers to constantly seek suitable solutions to address them, which may ultimately lead to the creation of new ideas. However, more than finding a solution alone is needed, as the engineering solution should be the best possible solution, considering all aspects. Achieving sustainable development goals, or in other words, designing sustainable structures, is one of the new challenges for engineers, which requires the development of appropriate regulations and frameworks. One of these targeted frameworks is green building rating systems.

Green building rating systems evaluate buildings based on available technology, efficiency, and the environmental performance of the building production and operation process, in a comprehensive and holistic approach, taking into account the building's life cycle and determining a final standard for what makes a building green in terms of design, construction, and performance. A summary comparison of some of the green building rating systems is presented in Table 1.

Table 1- An overview and comparison of several green building rating systems [2-6]

Name	LEED ²	BREEAM ³	Green Star	DGNB ¹
Country	USA	England	Australia	Germany
Creation Year	1998	1990	2003	2007
Rating Levels	Certified/Silver / Gold/Platinum	Pass/Good/Very Good/Excellent/Outstanding	1 to 6 Stars	Bronze/Silver/Gold
Criteria	Materials and resources, energy and atmosphere, water efficiency, sustainable sites, indoor environmental quality, innovation in design, regional priority.	Materials, energy, water, land use and ecology, health and well-being, waste, management, transportation, and pollution.	Materials, energy, water, land use and ecology, indoor environmental quality, management, transportation, emissions.	Ecological quality, sociocultural issues, technical quality, execution quality, economic quality, and site quality.
Name	China '3 Star'	Beam	Estidama	Green Mark

¹ Deutsche Gesellschaft für Nachhaltiges Bauen eV

² Building Research Establishment Environmental Assessment Method

³ Leadership in Energy and Environmental Design



			PBRS⁴	
Country	China	Hong Kong	UAE	Singapore
Creation Year	2006	1996	2008	2005
Rating Levels	1 Star to 3 Stars	Bronze/Silver/Gold/Platinum	1 to 5 Pearls	Certified/Gold/Gold Plus/Platinum
Criteria	Material and resource conservation, energy conservation and utilization, water conservation and utilization, land, and exterior environment conservation, indoor environmental quality, and operational management.	Topics related to materials, energy use, water use, site-related issues, indoor environmental quality, innovations, and increasing efficiency.	Monitoring materials, renewable energy, water consumption monitoring, natural systems, habitable buildings, innovation, and integrated development process.	Building efficiency, water efficiency, environmental protection, indoor environmental quality, and other green criteria.

In addition to the rating systems mentioned in Table 1, many other rating systems are used for grading green buildings in different countries. For example, in France, the HQE⁵ system is used, while in Japan, the CASBEE⁶ system is used, and in Portugal, the Lider A system is used. Many of these systems have been created by modifying and changing another system or by using multiple systems. For example, the Green Star system in Australia is based on the LEED and BREEAM systems, and the Beam system in Hong Kong is based on the BREEAM system [7]. Also, specialized versions of other systems are used in some countries, such as Green Star SA in South Africa and LEED Canada in Canada. In general, four main characteristics can be identified for all classification systems [2]:

- Creating motivation for sustainable activities
- Establishing a comparable standard for the sustainability of structures
- Creating a framework for defining sustainable design for engineers
- Creating practical and cost-effective tools for construction phases.

Although the ultimate goal of all rating systems is the same, there are differences in the evaluation criteria, the type of rating, and the scope of their application (existing buildings, under construction, residential, commercial, hospitals, etc.), making it impossible to compare the results of two rating systems in some cases. Furthermore, the existence of different rating systems indicates the importance of sustainable development in the construction industry, where other countries have planned for the long term and created comprehensive rating systems by green building standards tailored to their regional technologies and capacities to pursue sustainable development goals in a targeted and specific framework.

⁴ Pearl Building Rating System

⁵ Haute Qualité Environnementale

⁶ Comprehensive Assessment System for Building Environmental Efficiency



Another critical issue is the impact of these rating systems on advancing sustainable development goals, such as reducing energy consumption and improving the quality of life for people in the real world, where some results have been contrary to initial expectations. In a study conducted by John H. Scofield (2013) on a large number of office buildings in New York, it was found that only LEED gold-rated buildings have 20% less energy consumption and greenhouse gas emissions compared to non-rated buildings, while buildings rated with certified and silver ratings have higher energy consumption and greenhouse gas emissions than non-rated buildings [8]. Additionally, another study found that the satisfaction level of residents in LEED-rated office buildings did not differ significantly from that of non-rated buildings, and these residents had relatively higher satisfaction with indoor air quality and relatively higher dissatisfaction with the amount of light [9].

Therefore, without a doubt, the current rating systems still need to be completed and still require further research and review to achieve their primary goals.

3. Structural Engineer and Sustainable Development

Undoubtedly, structural engineers are one of the main pillars of the dynamic construction industry, facing more challenges than ever, including increasing environmental concerns and sustainable development. On the other hand, given the involvement of a team of different engineers in the construction process and the existence of common boundaries between their roles and responsibilities, achieving sustainable development requires raising awareness of each group and, in the next step, their familiarity and sufficient understanding of topics related to other groups and interaction for better implementation of sustainable development. Therefore, investigating, recognizing, and finding solutions to existing challenges related to each group of engineers is a prerequisite for success in sustainable development.

So far, compared to other groups of engineers (architects, environmental engineers, etc.), less attention has been paid to the role of structural engineers in sustainable development and within the framework of building rating systems [10]. Although the rating systems have evaluation criteria directly related to the design and specifications of the structure, and the structural engineer can directly play a role in them, according to a survey of active engineers in the field of sustainable development from all over the world, most of whom are structural engineers and sustainable design consultants, the results shown in Figure 1 were obtained by asking the question of how much of a role structural engineers play in the rating system evaluation process [2].

Although, according to Figure 1, half of the participants in the BREEAM system survey believe that structural engineers always or often have a role in the evaluation process, this belief is often accompanied by the opinion that this role and participation are unknown and indirect [2]. The main question is how structural engineers can play a more effective role according to their abilities.

It is expected that with the undeniable role of structural engineers in the construction industry, rating systems will undergo positive changes in this regard over time. It should be noted that in the new version of the LEED rating system (version 4, which has not been finally published at the time of writing), changes have been made in this regard so that in the new version, structural engineers are not limited to choosing materials to gain the necessary scores and can benefit from their skills in the design phases to create a truly sustainable design [11].

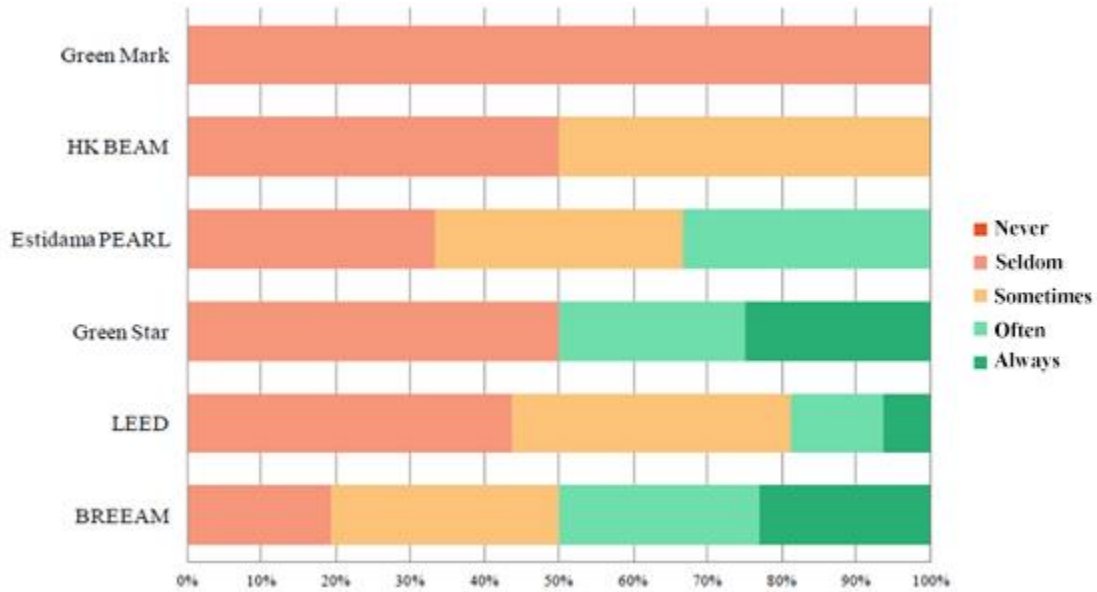


Figure 1 – Results of the survey on the role of structural engineers in the evaluation process of rating systems

On the other hand, structural engineers must be familiar with topics beyond the impact of structural systems and their responses to imposed loads. These topics may include a more precise understanding of the mutual effects of structural systems with other systems present in the building and their impact on the environment. To achieve this understanding, it is necessary to become familiar with the construction process of structural materials from manufacturing to installation, their effects on air quality, thermal performance, occupant comfort, and finally, their destruction or the possibility of recycling and reuse [12]. Learning and becoming familiar with this process enables us to expand our engineering perspective and establish suitable interaction with the environment and ecosystems while moving towards sustainable design .

Ultimately, the key to the success of sustainable construction lies in creating integrated and cohesive design and execution teams of responsible engineers in the construction industry who have an effective and active presence in all stages of design and implementation. This can be considered the third solution to increase the role of structural engineers in sustainable development and design, where the structural engineer can achieve a sustainable design through active interaction with other groups from the earliest stages of design .

Considering the proposed solutions that require increasing the level of knowledge of engineers and their interaction as much as possible, it can be expected that the concept of sustainable development will be well understood in the construction industry.

4. Principles of Sustainable Design

In general, the following principles can be considered for sustainable design [12]:

- Recyclable content: using recyclable materials is one of the most critical factors for sustainable development and the environment. Its importance is such that in the latest version of the LEED rating system, 10% recyclable content is mandatory for structural materials [11].



- Use of local materials and construction: the use of natural resources available on-site or near the project site and local capabilities and resources for construction and project implementation are among the topics discussed in sustainable design .

- Durability and reduction of maintenance and repair of structures: a durable and resilient building effectively and safely uses minimal additional resources for maintenance and repair over its lifetime, resisting environmental, structural, and operational needs. Sustainable design can result in constructing structures that do not require repair for years and have minimal maintenance and inspection costs.

- Design for adaptability and deconstruction (DFAD): adaptability means the structure's ability to adapt to various future uses with minimal cost and change. Additionally, considering the structure's condition after its lifespan is the subject of design for deconstruction or separation, which allows for easy and orderly separation of structural components, enabling their recycling and reuse if possible. Combining these two criteria increases the structure's lifespan and material recycling rate, reducing waste and simplifying installation and implementation.

- Reuse of buildings, structural components, and non-building structures: considering the reuse of buildings or parts of them through not requiring energy and water consumption to produce new materials and avoiding greenhouse gas and other related pollution has a very positive impact on the environment.

- Life Cycle Assessment (LCA): According to the definition of the Environmental Protection Agency (1993), "an assessment of all environmental impacts related to activities from the beginning of raw material collected from the ground until the waste returns to the ground" is called Life Cycle Assessment. Some environmental impacts include energy consumption, potential global warming, and the depletion of natural resources. Despite the complexity of LCA, this issue has become one of the main parts of sustainable building design with rapid progress.

- Structural materials and their toxicity: In a sustainable design, attention should be paid to the properties and performance of structural materials and the toxicity of their constituent parts. Its effects can affect the inhabitants of the structures, the environment, and even the workers who extract and build them .

Each of the items mentioned above has many details and explanations that are beyond the scope of this article. It is worth noting that the prerequisite for conducting sustainable design is sufficient familiarity with all these principles by all engineers involved in the design process, and providing many of these conditions requires innovation and creating new solutions, which is the main challenge in sustainable design.

5. Case Studies

In this section, we examine examples of structures with sustainable design. Reviewing these examples enhances engineering knowledge and demonstrates the practical application of the discussed topics.



5.1 The Traversina Bridge in Switzerland

Designed by Jurg Conzett in 1996, this bridge is one of the simplest examples of sustainable design (Figure 2).



Figure 2 – Traversina Bridge in Switzerland

Small local wooden sections were used in its design, and its foundations were designed to replace each wooden section without needing auxiliary bases (Figure 3). Therefore, the bridge structure can be maintained indefinitely using abundant local wood. This directly affects the performance of the structure's life cycle in terms of costs and environmental impacts [13].



Figure 3- wooden sections

5.2 Terminal B and the New Concourse at Mineta International Airport

The design of Terminal B and the New Concourse at Mineta International Airport in San Jose, United States, won the IDEAS2 award in 2011 for projects over 75 million dollars (Figure 4).



Figure 4- International Mineta Airport in San Jose

In this project's structural section, special bending moment-resisting frames (STMF) were used for the first time to create flexibility for future expansion and changes in spaces and for practical efficiency (Figure 5). The advantages of this frame include [14] :

- High flexibility and excellent seismic performance
- Providing all necessary elements despite geometric constraints
- Increasing adaptability and architectural space in the present and future
- Triple system performance, including resistance to gravity, earthquake, and wind loads
- Quick and easy installation due to the pre-fabrication of its components

Innovation, as one of the essential elements of engineering and sustainable design, has been well implemented in this project and has encompassed most of the criteria for sustainable design.



Figure 5- SMTF Frames

5.3 New Federal Building in San Francisco

This project was completed in 2007 and received a LEED Silver rating (Figure 6).



Figure 6- Federal Building in San Francisco

The following points are notable in the design of this building [15] :

- Innovation in the sunshade system
- Use of a natural ventilation system
- Use of underground parking
- Providing at least 50% of the building's electricity from renewable energy sources such as wind and solar energy
- Use of 50% blast furnace slag Portland cement in concrete construction.

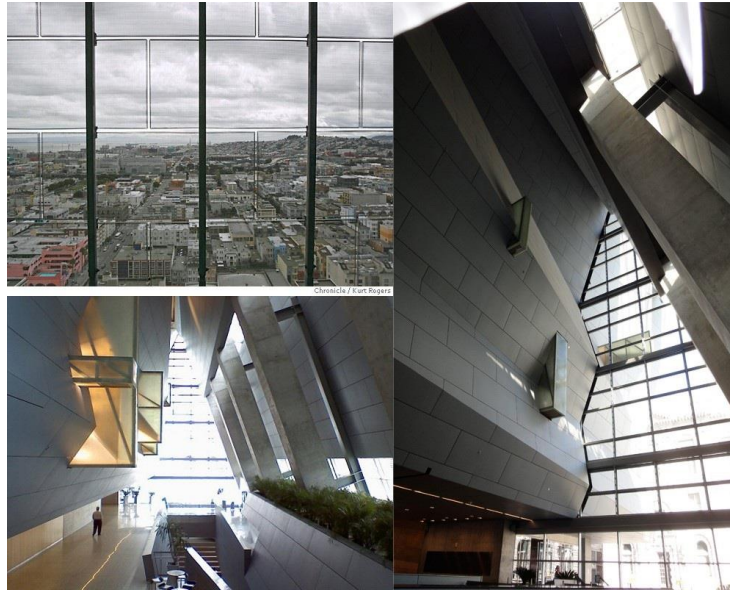


Figure 7- Federal Building Inner Space

6. Conclusion

Based on the discussions presented in this article, green building rating systems require further examination and review to achieve their predetermined objectives in practice. Additionally, the need to create a suitable regional rating system is evident, and a specific framework for designing buildings to consider sustainable design must be established.

It is essential for structural engineers to pay more attention to sustainable design issues and, by considering the proposed solutions and pathways, enhance their knowledge and awareness in this area to achieve their rightful place as one of the main pillars of the construction industry. However, this issue is also in the hands of effective interaction among engineers.

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7. References

- [1] Economic Do, Nations SAU. Indicators of sustainable development: guidelines and methodologies: UN, 2007.
- [2] Charlson A. The Value of Structural Engineering to Sustainable Construction (Final report). The Institution of Structural Engineers; 2012.
- [3] German Sustainable Building Council. Germany: DGNB Certification System; 2010.
- [4] Reed R, Bilos A, Wilkinson S, Schulte K-W. International comparison of sustainable rating tools. Journal of sustainable real estate. 2009;1:1-22.
- [5] Bitard P. Mini Study 08 – Scope for international cooperation on green building standards. DG Enterprise and Industry; 2009.
- [6] Council ADUP. Abu Dhabi Real Estate Market Forecasts. Retrieved from <http://www.upc.gov.ae>. 2010.
- [7] Fowler KM, Rauch EM. Sustainable building rating systems summary (No. PNNL-15858). Pacific Northwest National Lab(PNNL), Richland, WA (United States). 2006.
- [8] Scofield JH. Efficacy of LEED-certification in reducing energy consumption and greenhouse gas emission for large New York City office buildings. Energy and Buildings. 2013;67:517-24.
- [9] Altomonte S, Schiavon S. Occupant satisfaction in LEED and non-LEED certified buildings. Building and Environment. 2013;68:66-76.
- [10] Tabitha S. Stine SE, P.E., LEED AP BD+C. Structural Engineers and Sustainability. Modern Steel Construction Magazine 2012.
- [11] Weisenberger G. LET ENGINEERS BE ENGINEERS. Modern Steel Construction 2011.
- [12] Kestner DM, Goupil J, Lorenz E. Sustainability guidelines for the structural engineer: American Society of Civil Engineers (ASCE), 2010.
- [13] Ochsendorf J. Sustainable engineering: The future of structural design. Structures Congress 2005: Metropolis and Beyond 2005. p. 1-9.
- [14] Wendt G. Aviation Marvel. Modern Steel Construction. 2011.
- [15] New San Francisco Federal Building a Model of Sustainable Architecture. 2008.